WWRP WORLD WEATHER RESEARCH PROGRAMME

South African Weather Service

AvRDP OUTCOME

AvRDP Participating Airports

6+5 AvRDP AIRPORTS

AvRDP Airport	Climatological regime	Weather elements to be studied in AvRDP
Charles de Gaulle Airport (CDG) 	Mid-latitude in Northern Hemisphere Location: Inland	Winter weather - snowfall, icing, low temperature Fog
Hong Kong International Airport (HKG) 	Subtropical in Northern Hemisphere Location: Surrounded by water Next to high mountain	Convection and Thunderstorm Low visibility and ceiling
O.R. Tambo International Airport (Johannesburg Airport) (JNB) 	Subtropical in Southern Hemisphere Location: Inland	Convection Fog
Shanghai Hongqiao Airport (SHA) 	Subtropical/mid-latitude in Northern Hemisphere Location: Inland not far away from River Estuary and East China Sea	Convective weather
Toronto Pearson International Airport (YYZ) and **Iqaluit Airport (YFB)**  	Mid-latitude in Northern Hemisphere Location: Inland but not far away from Lake High-latitude in Northern Hemisphere Location: On Frobisher Bay	Winter weather – snowfall, icing, precipitation type and amount, visibility, wind speed, direction shear, and gust, turbulence, and low ceilings Convective Weather Artic weather – Winds, blowing snow, fog, visibility, ceiling

Changi Airport (SIN) 	Tropics 01°21'33.16" N103°59'21.5"E 2 Runways: 02/20 Location: Coastal	Convective Thunderstorm
Pulkovo Aiport (LED) 	Mid-latitude in Northern Hemisphere 59° 48' N 30° 15' E 2 Runways: 10/28 Location: Inland but between 2 Lake	Visibility and Cloud Ceiling
Indira Gandhi International Airport (IGI) 	Subtropic in Northern Hemisphere 28°34'07''N 77°06'44''E 3 Runways: 09/27 10/28 11/29 Location: Inland	Summer Convection Winter Fog/Low VIS
Tokyo Airport (Narita/Haneda Airport) 	Subtropic in Northern Hemisphere 35°45'55''N 140°23'08''E 2 Runways: 16/34 Near shore	Summer Convection A/P TS, Low VIS, Cloud ceiling winds ATC Sectors Convection Low level winds

Airport	Phase I (MET capability)	Phase II (MET-ATM translation)	User Benefit Demonstrated
CDG	High resolution nowcast model Winter fog nowcast Prob temp forecast	PEIP Runway State Prediction CDM@CDG Audit – benefit savings	CDM@CDG Daily operation Taxi time/Fuel/CO2/queueing/delay improved
HKG	Seamless blended nowcast High resolution AVM Satellite nowcast	Capacity Forecast Airport Departure Rate Simulation Optimal Trajectory	Daily airport capacity forecast Departure nowcast Optimised flight path
JNB	Convection nowcast High resolution model Lightning Nowcast	Impact Metrics Delay/Rate reduction/Stoppage	Impact proving to ATM Departure time and airport efficiency
SHA	Rapid Refresh Multi-module nowcast	Air route availability TRACON weather impact	Match better ATM needs Safety/regularity/efficiency improved
YYZ/YFB	Advanced airport observation equipment High resolution models Observation blended nowcast	Stopped	Failed to connect ATM
IGI	New airport instruments Fog model/satellite nowcast Thunderstorm/Dust Storm NWP	Upgrade weather briefing system	Better situation awareness
LED	New airport instruments Hourly updated NWP ABL Visibility and ceiling nowcast	Testing MeteoExpert Nowcast + Alpha ATM	More accurate aerodrome forecast & warning Better pre-operation briefing Improved capacity
NRT/HND	High resolution rapid outputs model nowcast	ATMet Category Impact of Wx Element prediction	Capacity nowcast Runway change Deviation
SIN	On-going – high resolution model	Not started	Not Yet

4 COMPONENTS

A. Nowcasting & mesoscale modelling Component

- (i) Radar-based nowcasting system or satellite-based nowcasting system, including human-machine interfaced and expert system-based system; **(Yes)**
- (ii) Convection-resolving mesoscale or microscale NWP model; **(Yes)**
- (iii) Blending of observations with high resolution NWP model; **(Yes)**
- (iv) Blending of radar/satellite-based nowcasting products with NWP system **(some);** and
- (v) Ensemble/probabilistic nowcasting product **(few)**

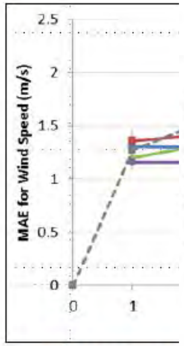
B. Verification Component (few, conventional skill scores)

C. MET-ATM Integration (most)

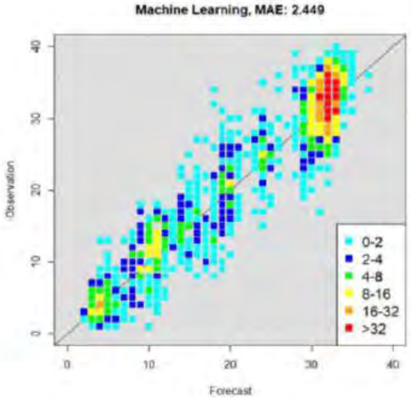
D. Capacity Building Component (2 workshops + 1 Semimar?)

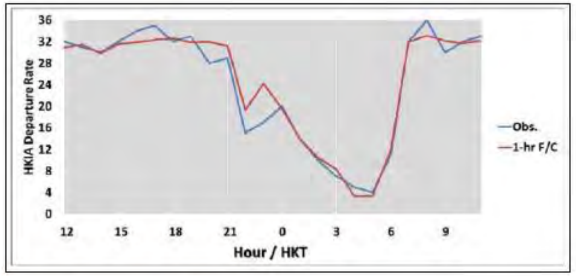
Continuous forecasts

- Comparison of continuous forecast and observed values (e.g., wind speed)
- Examples: Root Mean Squared Error (MSE), Mean Absolute Error (MAE), ME (Mean Error or Arithmetic Bias)
  - Note that scores are inter-related



CYYZ (Toronto) v

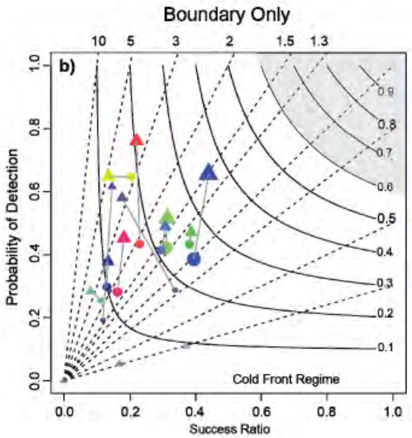




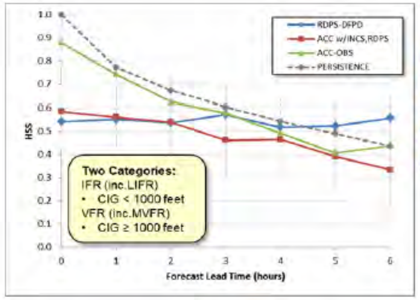
Departure Rate predictions
From HKO Final report for AVRDP (2019)

Categorical forecast examples

- Categorical statistics include
  - POD (Probability of Detection)
  - FAR (False Alarm Ratio)
  - CSI (Critical Success Index)
  - ETS (Equitable Threat Score)
  - HSS (Heidke Skill Score)
- Can be applied to yes/no decision making
  - Ex: Closing approach route due to convection



Example Performance Diagram for convective initiation forecasts (from Roberts et al. 2012; Weather and Forecasting)



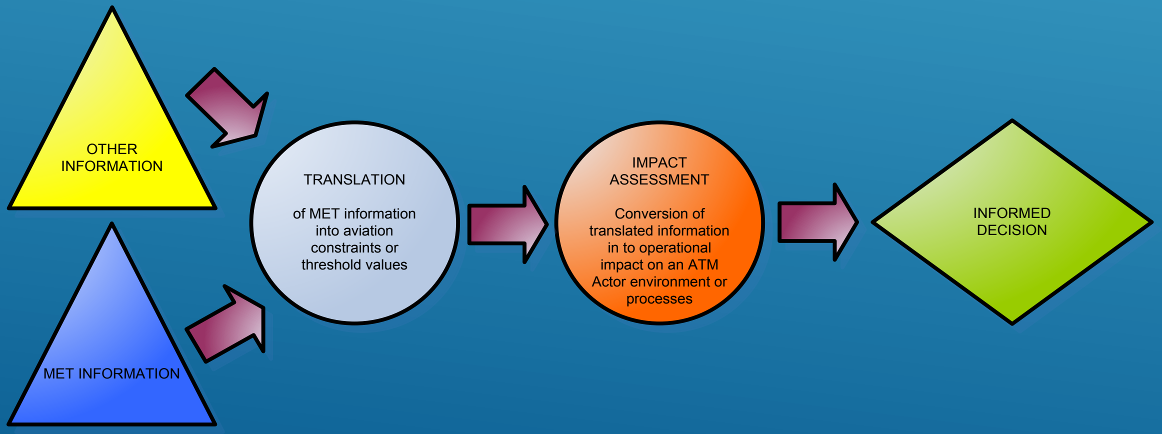
CYYZ (Toronto) verification; (Nov 2015 – Mar 2016). Credit: Janti Reid

Fig.10 POD, FAR and CSI of seabreeze occurrence prediction by AMV (resolution 200m) and NHM (resolution 2km)

From HKO Final report for AVRDP (2019)

ATM IMPACT

- Airport Capacity **(YES)**
- Airspace Capacity **(YES)**
- Arrival/Departure Delay **(YES/FEW)**
- Fuel consumption **(FEW)**
- Aircraft de-icing **(FEW)**
- Lightning strike affecting ground ops **(FEW)**



CAPACITY BUILDING

- Workshop I: Aviation Nowcasting and Mesocale NWP 22-24 July 2016, Hong Kong (http://wsn16.hk)
- **Workshop II:** WMO Voluntary Cooperation Programme (VCP) on the MET-ATM translation and integration, 8-10 October 2018, Hong Kong (https://worldweather.wmo.int/vcp_2018/index.php)
- Seminar: AvRDP Concluding Meeting, 19-22 Aug 2019, Pretoria, South Africa (https://avrdp.hko.gov.hk/meeting/seminar2019)

AVRDP TIMELINE

Nov 2014	**Endorsement of the AvRDP proposal by WWRP SSC**
Nov 2014 – Feb 2015	Formation of AvRDP SSC and identification of AvRDP Participants
24 – 26 Jun 2015	Kick-off Meeting cum Science Meeting
May 2015 – 2017+	***Phase I – MET capacity research***
May 2015 - Oct 2015	1st IOP for convective weather (over Airports in Northern Hemisphere)
Nov 2015 – Mar 2016	1st IOP for winter weather, visibility and ceiling (over Airports in Northern Hemisphere)
Dec 2015 – Mar 2016	2nd IOP for convective weather (Southern Hemisphere)
May 2016 – Jul 2016	3rd IOP for convective weather (Northern Hemisphere)
Nov 2016 – Mar 2017	2nd IOP for winter weather, visibility and ceiling (Northern Hemisphere)
May 2015 – Jul 2017	Nowcasting research including MET verification on convective weather
Nov 2015 – Jul 2017	Nowcasting research including MET verification on winter weather, visibility and ceiling
20 - 22 Jul 2016	1st AvRDP Training Workshop on aviation nowcasting and mesoscale modelling
22 – 23 Jul 2016	2nd SSC Meeting
25 – 29 Jul 2016	Preliminary Phase I results presented in WWRP Symposium on Nowcasting and Very-short-range Forecast
Jul 2016 – Sep 2019	***Phase II – MET-ATM impact translation and validation (some airports started later)***
Jul 2016 –	Research on MET-ATM impact translation
Jul 2017 –	Demonstration of MET-ATM impact
6 - 10 Nov 2017	AeroMetSci-2017 Conference & 3rd SSC Meeting
Jan 2018	4 more airports joined the Project
8 -10 Oct 2018	2nd AvRDP Training Workshop on ATM-MET integration
11 – 12 Oct 2018	4th SSC Meeting
Oct 18 – Sep 2019	Continue MET-ATM impact translation and demonstration
Aug 2019	Concluding Meeting & Seminar
	Extended Aviation Research Project ?

Phase I

Phase II

Complete

CONTRIBUTIONS TO ASBU

B0 (2013+)

AMET-B0/1	Meteorological observations products
AMET-B0/2	Meteorological forecast and warning products
AMET-B0/3	Climatological and historical meteorological products
AMET-B0/4	Dissemination of meteorological products

improved situational awareness, collaborative decision-making and dynamically optimized flight trajectory planning

B1 (2019+)

AMET-B1/1	Meteorological observations information
AMET-B1/2	Meteorological forecast and warning information
AMET-B1/3	Climatological and historical meteorological information
AMET-B1/4	Dissemination of meteorological information

Meteorological forecast and warning information for automated support for decision processes or aids and performance based requirements, involving **meteorological information, meteorological information translation, ATM impact conversion and ATM decision processes.**

B2 (2025+) AND B3 (2031+)

B2 (2025+)

AMET-B2/1	Meteorological observations information
AMET-B2/2	Meteorological forecast and warning information
AMET-B2/3	Climatological and historical meteorological information
AMET-B2/4	Meteorological information service in SWIM

- **Forecast and warning services for terminal areas.**
- **Higher spatial and temporal resolution of meteorological forecasts and warnings.**

- Further development of probabilistic information derived from ensemble prediction systems

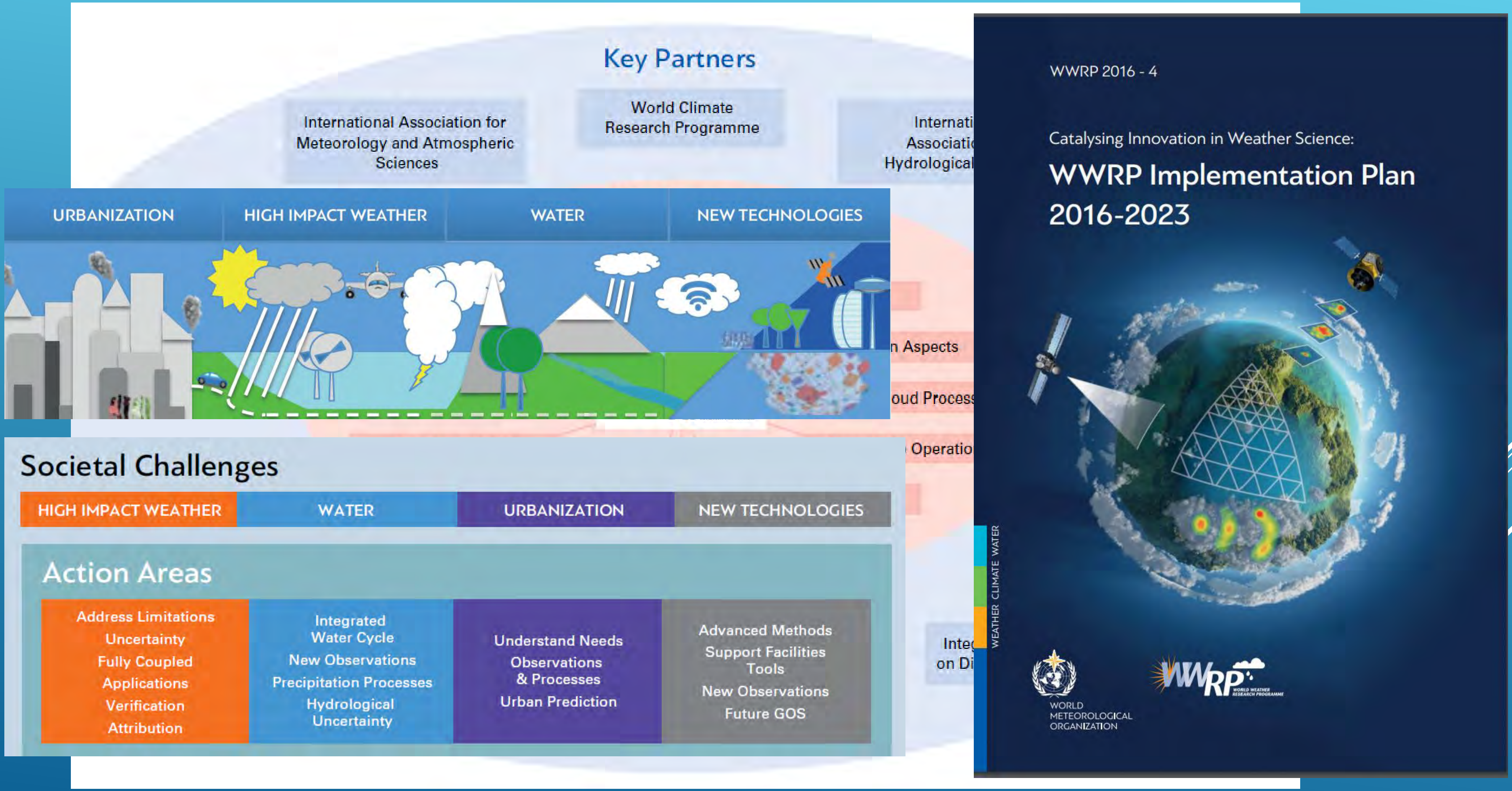
B3 (2031+)

AMET-B3/1	Meteorological observations information
AMET-B3/2	Meteorological forecast and warning information
AMET-B3/3	Climatological and historical meteorological information
AMET-B3/4	Meteorological information service in SWIM

- **Forecast and warning services for terminal areas.**
- **Higher spatial and temporal resolution of meteorological forecasts and warnings.**

- Further development of **probabilistic** forecast information.
- Further development towards a fully integrated meteorological forecast service fit for the purpose of all flight phases and ATC operations, in support of gate-to-gate seamless operations

WWRP IMPLEMENTTION PLAN



PRIORITY AA1: ADDRESS LIMITATIONS

- Achieved
  - Identified gaps between existing MET capabilities and the ICAO GANP ATM requirements, via the AeroMetSci-2017 Conference
  - Identified aviation operations' needs in terms of probabilistic/confidence information
  - Improved aviation nowcasting and meososcale modelling capabilities in terminal areas
  - Improved interaction/integration between MET office and ATM operations (on-going)
- Plan
  - More aviation hazard and MET forecast capability enhancement to be studied via an extended Aviation Research Project from 2020 (subject to the endorsement by …)

PRIORITY AA4: APPLICATIONS

- Achieved
  - Identified ATM and airlines requirements.
  - Confirmed MET is the enabler for the modernization of growing global air traffic to maintain safety, efficiency and environment responsiveness
  - Translating the enhanced MET capabilities into ATM Impact parameters (on going)
  - Establishing tighter interaction between MET and ATM via the Project (on going)
- Plan
  - An extended Aviation Research Project to further the above applications (subject to endorsement by …)

PRIORITY AA14: ADVANCED METHODS

- Achieved
  - Developed a few nowcasting and high resolution, rapidly updated, rapidly output NWP to ATM parameter (on going)
  - Employment of new MET observations for aviation studies (on going)
  - Developing new techniques (e.g. multi-spectral satellite data) for identification of aviation meteorological hazards (on going)
- Plan
  - An extended Aviation Research to further the development of new observations and advanced aviation meteorological information and techniques (subject to endorsement by …)

AvRDP Website (https://avrdp.hko.gov.hk)

GAPS

EC-71 (2019)

44 (EC-68) Intercommission Aviation Research Project

"2019 last year of the Aviation RDP, outcomes will be reviewed by WWRP SSC in October, and CAS and CAeM will analyse the next step"

Feedback from workshop participants

Need to improve?

- Nowcasting
- Improve the forecast

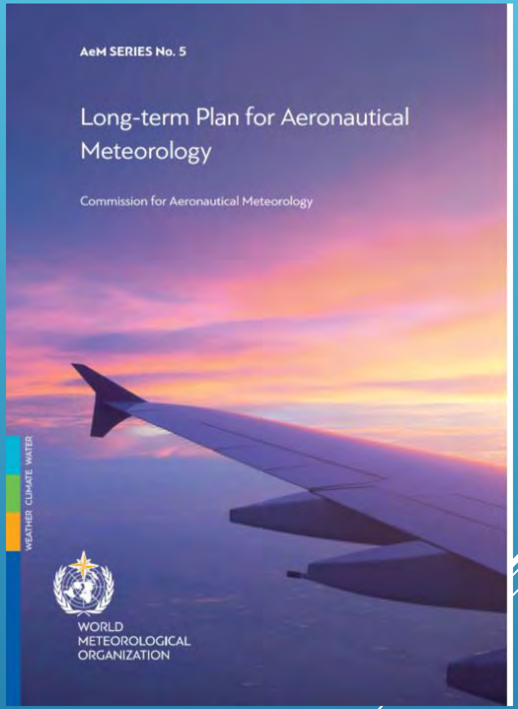
- How to start and proceed with the collaboration with ATM
- To start identify the MET information that is important for collaboration with ATM
- Business cases for MET-ATM integration
- MET-ATM Impact translation and integration and validation
- New blending of products, visualization and impacts
- Share the workshop information with the relevant stakeholders, including ATC and airlines

- How to adapt or implement IWXXM (more on IT)

AeM LONG TERM PLAN

https://www.wmo.int/aemp/LTP-AeM

- Seamless regional/global models of service delivery
- Driven by user requirements
- It's all about the (best) data
- Integration and interoperability
- WMO key roles in science, technology, data and observations, including aircraft-based observations
- Roles of AMSPs – public and private sector



STAKEHOLDERS' VISIONS

(A) IFALPA Vision for the Future Weather Information (IFALPA, June 2018)

1. EFB
2. Information Uplink
3. Shared situation awareness
4. Real-time weather update
5. High resolution ground radar
6. Forecast en-route turbulence, wind, thunderstorm …
7. Colour charts
8. Training

IFALPA
The Global Voice of Pilots

Position

18POS03 **June 2018**

IFALPA Vision for the Future of Air Navigation and Weather Information

This document (18POS03) replaces 15POS18 - The Future of Air Navigation and Weather Information. The changes include the removal of some outdated images and charts.

INTRODUCTION

Since its founding in 1948, IFALPA has always striven to be at the forefront of developments within aviation. In some areas of this endeavour there have been dramatic changes in air navigation, the pace has been gradual with periodic step changes. However, in recent years with the advent of the liberalisation of the airline industry there has been an unprecedented growth in air traffic volume. The growth has, at times, threatened to overwhelm the existing system capacity and a paradigm shift is required for the system to safely keep pace with the explosion in demand. Against this challenging background, and apart from Air Traffic Management (ATM) driven needs for new technologies there have also been developments in the military sector, specifically the growth in Remotely Piloted Aircraft (RPA) technology which has entered the civil arena. Clearly, this also presents significant threats not only for the future of the profession but more importantly, the safety of the air transport system. While the vision originally outlined in this document was rooted in Air Traffic Management work it rapidly became apparent that the outcome of this technical revolution would have an impact on the profession in a much wider context.

STAKEHOLDERS' VISIONS

(B) ECA Vision – Recommendation and action on The weather information need for safe operations (EASA Workshop. January 2018)

1. Education and training; weather hazards, mitigation
2. Improved weather briefing presentation
3. Promotion of in-flight weather information updates (EFB)
4. Pan-European high resolution forecasts - CAT, icing, surface winds, CB, winter weather
5. Development and enhancement of aircraft sensors/solutions
6. Connectivity to support in-flight updated of meteorological information (uplink)
7. Provision of enhanced meteorological information - high resolution observed and forecast meteorological information with high spatial and temporal resolution such as imagery derived from satellite and ground weather radar sources.

STAKEHOLDERS' VISIONS

(C) ICAO White Paper

- High Altitude Ice Crystals (HAIC)[9] and airframe icing;
- All forms of turbulence;
- Significant convection;
- Detection and prediction of low-level wind shear and wake vortex;
- Low visibility including fog;
- Space weather;
- Atmospheric aerosols including volcanic ash and potentially other gases;
- Observing methods (in-situ and remote sensing) and use of observations, including those from aircraft, other airborne platforms and from space;
- Nowcasting and probabilistic forecasts; and
- Seasonal (3-6 months ahead) forecasting

WMO AeroMetSci Conference 2017, http://www.wmo.int/aemp/AeroMetSci-2017

Key Area 1: Aeronautical Meteorology Science	Key Area 2: MET-ATM Integration	Key Area 3: Climate Change and Impact on Aviation
• Ice crystal icing and airframe icing research	• In-cockpit and on-board MET capabilities	• Building awareness of potential impacts
• Turbulence research	• Terminal area and impact-based forecast	• Jet stream position and intensity and related phenomena, such as CAT
• Significant convection research	• En-route hazards information systems	• Extreme weather events and airports, changes to typical scenarios (storm surges, heat waves, visibility regimes, etc.)
• Wake vortex detection and prediction	• Translation of MET information for impact and risk assessment	• Re-evaluation of airframe/avionics resilience standards and certification
• Fog/low visibility research	• Collaborative decision-making (CDM), air traffic flow management (ATFM) and network management	• Focus on downscaling of aviation impacts to regional and local scale
• Space weather research	• Trajectory-based operations (TBO), flight planning and user-preferred routing	
• Atmospheric aerosols and volcanic ash research	• Use of MET information for climate-optimized trajectories	
• Advances in observing methods and use of observations		
• Seamless nowcast and numerical weather prediction, probabilistic forecast and statistical methods		

VISION

RESEARCH NEEDS (PROJECT OUTCOMES AND OTHER VISIONS)

(A) Improvement of weather information in weather phenomena

1. Ice crystal icing and airframe icing
2. Turbulence (CAT & CIT)
3. Significant Convection
4. Detection and prediction of low-level windshear and wake vortex
5. Low visibility including fog
6. Space weather
7. Atmospheric aerosole and volcanic ash (IAVW)

(B) Improvement in observation and forecasting techniques

1. Advances in observing methods and use of observations (ground base and airborne)
2. Seamless nowcast and numerical weather prediction
3. Probabilistic forecast and statistical methods (uncertainty/confidence)
4. Aviation Verification and Validation

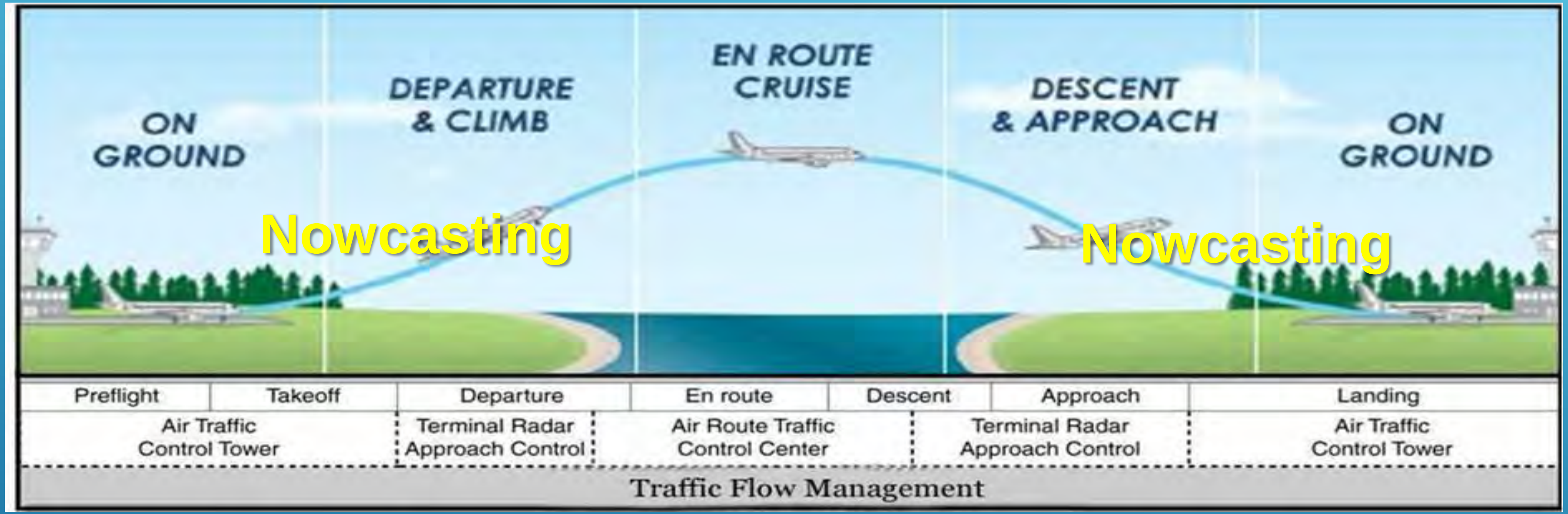
(C) Integration of MET and ATM to support ATM/Airline operations (with user engagement)

1. Impact translation
2. Provision of EFB
3. Uplink latest weather information
4. Simulation for optimizing flights to improve safety and capacity

Trajectory-based operation (TBO)

- Seamless MET information, not bounded by FIR
- Trajectory-based operation; gate-to-gate info

Seamless nowcasting -> mesoscale -> global scale -> mesoscale -> nowcasting scale



Terminal Control Area: Location specific

En Route Phase: Supported by Satellite and models

Terminal Control Area: Location specific

DISCUSSION

- Priority?
- Time frame?
- Thread with other ASBU module?
- Core Project or individual projects?